PATENT SPECIFICATION 704,609

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COMPLETE SPECIFICATION.

Improvements in or relating to Multi-stage Axial-flow Compressors or Turbines.

We, ROLLS-ROYCE LIMITED, a British Company, of Nightingale Road, Derby, in the County of Derby, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement :

This invention relates to axial-flow turbo-machines, that is multi-stage axial-flow compressors and turbines as used in gas-turbine engines, and is concerned more especially with rotor constructions for such machines.

The object of the invention is to provide a simple, light and inexpensive form of rotor suitable for use at high rotational speeds.

According to this invention, a rotor for an axial-flow turbo-machine, such for instance as the rotor of an axial-flow compressor of a gas-turbine engine, comprises a plurality of stages of rotor blading, a plurality of discs one for each of said stages of blading, and a metal shell to afford the inner wall of the working fluid passage of the turbo-machine, said discs being arranged in axially-spaced relation in and being located with respect to the shell, each said disc being slotted to receive and to have rigidly secured therein, as by brazing, the ends of the blade elements of the associated stage of blading, and there being apertures in the shell to permit the blades to extend freely through the shell into the slots.

The discs may be located by having their peripheries brazed to the inner surface of the shell, or may have a diameter less than the internal diameter of the shell and have annular sheet-metal discs brazed to their axially-facing surfaces, which sheet-metal discs extend outwards from the blade-carrying discs and are brazed to the shell.

The blades are preferably of substantially uniform aerofoil section throughout their length and may be secured to the discs in the manner described in the Specification of co-pending British Patent Application No. 19183/50 (Serial No. 694,651).

When the discs are brazed directly to the shell, brazing is preferably only effected intermediate the blades so that the discs carry the radial loads and the shell holds the discs in their appropriate axial spacing, transmits the torque between the discs and takes the bending loads. The rotor of this invention has no central shaft and has a high whirling speed. The shell is thin and may be a forging or made from sheet metal.

The shell will normally be of conical form and of uniform thickness and in this case the peripheral surfaces of the discs may be made conical to conform to the inner surface of the shell ; or the inner shell surface may be made mainly conical and be formed with cylindrical lands at the axially-spaced locations of the discs which, in this case, will have cylindrical peripheral surfaces ; in the latter arrangement, the shell may also be formed internally with annular, axially-directed locating shoulders for the discs, the shoulders being on the side of the cylindrical lands adjacent the smaller diameter end of the shell to facilitate axial positioning of the discs.

Some constructions of rotor for an axial-flow compressor embodying the above and other novel features of this invention will now be described with reference to the accompanying drawings in which :—

Figures 1A and 1B illustrate a compressor rotor suitable for being driven by a coaxial turbine ;

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Figures 2 and 3 illustrate slight modifications of the arrangement shown in Figure 1A ;

Figure 4 illustrates yet other slight modifications ;

Figure 5 illustrates another modification employing a construction similar to that of Figure 4 ;

Figures 6 and 7 show two further modified arrangements, and

Figure 8 shows yet another modification.

Referring to Figures 1A and 1B, the rotor illustrated comprises a compressor drum 10 for an axial-flow compressor and a tubular shaft 11 for interconnecting the compressor rotor with the rotor of a coaxially-arranged turbine.

The compressor drum comprises a forged shell having a conical portion 12 the external surface of which affords the inner wall of the working fluid passage of the compressor, and an end portion 12A closing the narrower end of the shell and having projecting therefrom a stub shaft 13 by means of which the forward end of the compressor is supported in associated stationary structure part of which is shown at 14. The part 14 is a bearing housing and supports a bearing 15 the rotating race 15A of which is mounted on a step of the shaft 13.

The rotor drum also comprises a plurality of stages of compressor rotor blading *16a*, *16b*, *16c*, *16d*, *16e*, *16f* and *16g*, of which the first stage rotor blading *16a* is located upstream of the forward end of the conical portion 12 of the shell, being supported on the periphery of a disc 17 mounted on the forward end of the stub shaft 13 and held in abutment with the race *15a* by means of a ring nut *13a* threaded on to the end of the stub shaft 13.

The rotor drum also comprises a series of discs *18c*, *18d*, *18e*, *18f* and *18g* within the shell, which discs are associated respectively with the stages of rotor blading *16c*, *16d*, *16e*, *16f* and *16g*. Each disc is thickened peripherally as indicated at 19 and is gashed so as to be capable of receiving the ends of the associated rotor blades, the blades passing through slots 20 cut in the conical portion 12 of the shell. The disc rims 19 have a less axial dimension than the chordal dimension of the blades and the blades are brazed into the slots gashed in the disc rims 19.

The peripheral surface of the rim 19 of each of the discs *18c*, *18d*, *18e*, *18f*, is cylindrical and engages a cylindrical seat 21 machined on the internal surface of the conical portion 12 of the drum. The seats 21 are machined in radially-thickened parts of the conical portion 12 which afford smaller diameter cylindrical lands and thus leave axially-facing shoulders 22 at the ends of the cylindrical seats 21 remote from the larger end of the conical portion 12. The shoulders 22 serve to locate the discs *18c*, *18e*, *18f*, *18g* axially with respect to the shell. The discs may be secured to the conical portion 12 of the shell by brazing intermediate the slots 20 and may also be pegged to the conical portion 12, as indicated by the pegs 23 which pass through the shell into holes 24 in the rims 19 of the discs, to locate these parts during brazing.

By brazing the blades into the slots in the discs rims 19 and brazing the shell to the disc rims 19 intermediate the slots, the discs carry the radial loads developed in use of the compressor rotor and the shell holds the discs in their appropriate axial spacing, transmits the torque between the discs and takes the bending loads.

The disc *18g* has a pair of axial flanges 25 and 26 extending from its rim 19 and the flange 25 fits within the shell and the flange 26 forms a socket to receive a cylindrical end *11a* of the shaft 11. The flanges 25 and 26 may be secured to the conical portion 12 of the shell and the cylindrical portion *11a* of the shaft respectively by pegs such as the pegs 23 and will also be brazed to these parts.

The second stage rotor blading *16b* is in this construction secured in slots in a ring 27 and the ring is mounted on the forward end of the shell being engaged on a cylindrical seating 28 at the level of the end wall *12a*. The ring is brazed to the seat 28 and may also be located by pegs 23 as in the case of the discs *18c*, *18d*, *18e*, *18f*, *18g*. The ring 27 has a radial flange *27a* into which may be threaded studs 29 which may be used for balancing purposes.

The shaft 11 is conveniently a forging and has downstream of the cylindrical portion *11a* a series of circumferential ribs *11b* for co-operation with fixed elements of a labyrinth type seal. The downstream end of the shaft 11 is of smaller diameter than the cylindrical portion *11a* and is formed with an inwardly-directed radial flange *11c* by which the shaft 11 is connected to the turbine rotor. The downstream end portion of the shaft 11 is connected to the cylindrical portion *11a* by a convergent portion *11d*.

The rotor drum 10 has no central shaft and it therefore has a high whirling speed. However a tube 30 may extend centrally through the rotor drum 10 and shaft 11 for conveying oil from the forward end of the compressor to the compressor and turbine bearings and the tube may be supported at a number of points in its length. For instance the disc *18g* is shown as having axial extensions 31 at its centre into which extensions towards their outer ends are fitted collars 32 secured on the outside of the tube 30. An additional support is provided in the shaft 11, this support being in the form of a dished disc 33 having at its

centre axial extensions 34 engaging adjacent their outer ends lands 35 on a sleeve 36 secured on the tube 30.

Referring now to Figure 2, there is illustrated a slight modification in which instead of the blade-carrying discs having cylindrical surfaced rims 19, the peripheral surfaces of the rims are conical, as indicated at 19*a*, and the conical portion 12 of the shell is of uniform thickness and is thus internally conical. As in the previous construction, the external surfaces of the disc rims 19 seat against the inner surface of the conical portion 12 and are brazed thereto.

Moreover in the arrangement of Figure 2 the ring 27 bears at its downstream end against a radially-extending shoulder 37 which is formed with a groove 38 to receive a copper ring to permit the downstream surface of the ring 27 to be brazed to the shoulder 37. In this construction moreover the ring 27 is of less axial dimension than the chordal dimension of the rotor blades 16*b* and the trailing edges of these blades are arranged to project over the conical surface of the conical portion 12 of the shell.

Referring now to Figure 3, there is illustrated another form of interconnection between the blade-carrying discs and the conical portion 12 of the shell. In this construction the peripheral surfaces of the rims 19 are again cylindrical and they engage cylindrical surfaces 40 machined on the inner surface of the conical portion 12 to extend axially from radially-inwardly-projecting annular ridges 41 which act to locate the discs axially within the shell. In this construction the cylindrical seat 40 extends axially for a distance substantially equal to the axial width of the rims 19 of the discs and the blades have their leading and trailing edges cut away as indicated at 42 so that the slots in the conical portion 12 of the shell need not extend axially beyond the axially-spaced edges of the peripheral surface of the associated rim 19.

The stub shaft for supporting the forward end of the rotor drum 10 need not be made in one piece with the rotor drum and the arrangements shown in Figures 4 to 7 all employ a stub shaft which is separate from the shell.

Referring to Figure 4, the shell 112 is conical both internally and externally and is provided at its upstream end with a thickened bead 112*a*. The upstream end of the shell 112 is closed by a disc 45 having a thickened rim 45*a* which is slotted to receive the row of rotor blades 16*b* and which has an axial tapering extension 45*b*, the downstream edge of which is rolled or peened over behind the bead 112*a* to retain the disc in position on the end of the shell 112. The disc is then brazed to the shell. The disc has formed centrally of it the stub shaft 13 by which the compressor drum 10 is mounted in stationary structure.

The discs 18*c*, 18*d*, 18*e*, 18*f*, 18*g* are engaged with the shell 112 in the same manner as was described with reference to Figure 2.

Referring to Figure 5, there is illustrated an alternative arrangement to that illustrated in Figure 4, and in this construction the bead 112*a* is formed on the end of a separate ring 112*b* which is butt-welded to the end of the main shell 112. The disc 45 connected to the ring 112*b* in the same way as was described with reference to Figure 4 for connecting the disc 45 to the shell 112. A groove may be cut in the ring 112*b* for the insertion of a copper bead to facilitate brazing the ring to disc 45.

The discs fitting internally of the shell 112 are similar to those illustrated in Figure 2 but in this arrangement the associated blades are shown as being cut away adjacent their leading and trailing edges to form root portions having a chordal dimension substantially equal to the axial dimension of the disc rims 19.

Referring now to Figures 6 and 7 two similar arrangements are illustrated, the arrangement of Figure 6 being suitable for use when the parts of the rotor drum 10 are formed from steel and the arrangement of Figure 7 being suitable when the parts of the rotor drum 10 are formed from an aluminium alloy.

In each of these constructions the shell 212 is either formed from sheet-metal or as a forging and is of uniform thickness throughout its length. The blades 16 of the intermediate stages of blading are carried on discs 218 which are of uniform thickness and are externally of conical form to seat against the internal surface of the shell 212. The discs 218 are of a less axial dimension than the chordal dimension of the associated blades 16 and the shell is slotted to permit the root ends of the blades to pass freely through the shell 212 into engagement with radial slots in the discs 218.

The row of blades 16 at the inlet end of the rotor drum 10 extend through the shell 212 and are brazed into radial slots in the periphery of a thick, dished plate 219 fitted in the narrower end of the shell. The dished plate 219 has a conical peripheral surface which engages with a conical portion of the internal surface of the shell and this plate has formed integrally with it a shaft 213 by which the forward end of the compressor rotor drum 10 is supported in associated stationary structure by a bearing 215.

The outlet row of rotor blades 16 pass through the shell 212 as do the other rows of blades but their supporting disc 220 is axially flanged to give it a larger bearing surface against the shell 212 and is provided with bolt holes 220*a* to permit connection of

the rotor drum 10 to a driving shaft, and a flange 220*b* which may form a spigot portion of a spigot and socket joint between the disc 220 and the shaft.

The shell is brazed to the discs 218, 220 and plate 219 at points intermediate the slots in the shell, and the blades are brazed by their roots in their slots.

It will be noticed that in the arrangement suitable for use with an aluminium alloy rotor drum, the plate 219 is substantially thicker than when the rotor is constructed from steel. Moreover it will be noticed that the discs 218 and 220 are thicker when they are made from aluminium alloy than when they are made from steel.

Referring now to Figure 8, there is illustrated a construction of rotor having a conical shell of uniform thickness 212, and in this construction the discs 318 for carrying the blades 16 have a maximum diameter substantially less than the internal diameter of the shell 212. The blades 16 are formed with elongated root portions 316 which extend through the shell 212 and engage slots in the peripheries of the discs 318 and the root portions 316 are brazed in the slots. The discs 318 are located with respect to the shell each by means of a pair of sheet-metal discs 319 which are brazed to each face of the blade-carrying discs 318 and have axial flanges 319*a* on their outer edges brazed to the shell 212. As in the previous constructions the blades 16 pass freely through the shell not being brazed thereto.

The tubular shaft 11 above referred to may be made in one piece to extend from the compressor rotor to the turbine or may be made in a number of parts butt-welded together. For instance, the parts 11*d*, 11*a* may be separate from the remainder which may be cylindrical drawn tube.

The brazing may be carried out in a number of steps, say first brazing the shell to the discs at a comparatively high temperature and then the blades to the discs at a lower temperature.

The discs may have central holes to allow the passage of, say, oil pipes as indicated in Figures 1A and 1B and these holes also allow "purging" of the interior of the rotor drum during brazing.

What we claim is :—

1. A rotor for an axial-flow turbo-machine comprising a plurality of stages of rotor blading, a plurality of discs one for each of said stages of blading, and a metal shell to afford the inner wall of the working fluid passage of the turbo-machine, said discs being arranged in axially-spaced relation in and being located with respect to the shell, each said disc being slotted to receive and to have rigidly secured therein the ends of the blade elements of the associated stage of blading, and there being apertures in the shell to permit the blades to extend freely through the shell into the slots.

2. A rotor as claimed in Claim 1 wherein the blades have their ends rigidly secured in the discs by brazing.

3. A rotor as claimed in Claim 1 or Claim 2, wherein the discs are located by having their peripheries brazed directly to the shell.

4. A rotor as claimed in Claim 1 or Claim 2 or Claim 3, wherein the shell is of generally conical form and the disc peripheries are also conical to conform to the inner surface of the shell.

5. A rotor as claimed in Claim 1 or Claim 2 or Claim 3, wherein the shell has an inner surface which is mainly conical and is formed at the axially-spaced locations of the discs with cylindrical lands and wherein the disc peripheries are correspondingly cylindrical.

6. A rotor as claimed in Claim 5, wherein the shell is formed internally with annular, axially-directed locating shoulders for the discs, the shoulders being on the side of the cylindrical lands adjacent the smaller diameter end of the shell to facilitate axial positioning of the discs.

7. A rotor as claimed in Claim 6, wherein the shoulders are in the form of radially-projecting, annular ridges.

8. A rotor as claimed in Claim 7, wherein each shoulder extends between a pair of radially-spaced cylindrical lands at the location of each disc.

9. A rotor as claimed in any of Claims 1 to 8, wherein the rotor comprises also a stub extending from it adjacent its upstream end.

10. A rotor as claimed in Claim 9, wherein the shell is closed at its upstream end by an end wall formed in one piece therewith and wherein the stub shaft projects centrally from the end wall.

11. A rotor as claimed in Claim 10, wherein a stage of rotor blading adjacent the upstream end of the shell is secured in a ring separate from the shell and mounted on and brazed to a seat formed adjacent the upstream end of the shell.

12. A rotor as claimed in Claim 11, wherein the seat for the ring is cylindrical and the ring is located axially on the upstream end of the shell by abutment with a radially-extending shoulder on the shell.

13. A rotor as claimed in Claim 9, wherein the stub shaft is formed centrally of a disc or plate for carrying a ring of rotor blades adjacent the upstream end of the shell and the disc or plate is fitted to the upstream end of the shell.

14. A rotor as claimed in Claim 13, wherein the disc having the stub shaft formed in one piece therewith is located axially beyond the end of the shell and is

the working fluid passage of the turbo-machine, said discs being arranged in axially-spaced relation in and being located with respect to the shell, said discs being slotted to receive the ends of the associated blades, and there being apertures in the shell to permit the blades to extend freely through the shell into the slots.

The discs may be located by having their peripheries brazed to the inner surface of the shell, or may have a diameter less than the internal diameter of the shell and have annular sheet metal discs brazed thereto and extending outwards therefrom to be brazed to the shell.

The blades are preferably of substantially uniform aerofoil section throughout their length and may be secured to the discs in the manner described in the Specification of co-pending British Patent Application No. 19183/50 (Serial No. 694,651).

When the discs are brazed directly to the shell, brazing is preferably only effected intermediate the blades so that the discs carry the radial loads and the shell holds the discs in their appropriate axial spacing, transmits the torque between the discs and takes the bending loads. The rotor of this invention has no central shaft and has a high whirling speed. The shell is thin and may be a forging or made from sheet metal.

The shell will normally be of conical form and the peripheral surfaces of the discs may be made conical to conform to the inner surface of the shell; or the inner shell surface may be made mainly conical and be formed with cylindrical lands at the axially-spaced locations of the discs which, in this case, will have cylindrical peripheral surfaces; in the latter arrangement, the shell may also be formed internally with annular locating shoulders for the discs, the shoulders being on the side of the cylindrical lands remote from the larger diameter end of the shell.

Some specific constructions of rotor for an axial-flow compressor embodying the above and other novel features will now be described.

In one construction, the rotor comprises a frusto-conical shell of uniform thickness which shell is either a forging or sheet metal. The rotor comprises also a series of discs one for each of a plurality of stages of rotor blades, and all the discs except the discs for the first and last stages of rotor blades are plane, have their peripheries conical to fit the inner surface of the shell at the proper axial location for its stage of blades, and have their peripheries gashed radially to receive the root ends of their respective stage of rotor blades. The axial dimension of these discs is substantially less than the chordal dimension of the associated blades. The disc for the first stage is dished for strength, has a thickened rim shaped to fit the narrower end of the shell and gashed to receive the blade roots, and is formed centrally with a stub-shaft to be engaged by the front bearing for the rotor. The disc for the last stage is similar to those for the intermediate stage except that it is provided near its periphery with axially-extending flanges to spigot with the end of a shaft connecting the rotor to a driving turbine and that it is adapted to be bolted to the shaft or a flanged part thereon.

The shell is apertured in the region of the discs to permit the root ends of the blades to pass freely through the shell which is brazed to the disc peripheries intermediate the blades. The blades are brazed in position in the disc.

The discs and shell may be formed from either steel or aluminium.

In another construction, the shell is similar to that just described except that it extends from the second row of rotor blades to just upstream of the last row of rotor blades. The intermediate discs instead of being plane are slightly thickened at their centres and have widened rims to receive the blades.

The last disc also has axial flanges one to spigot into the end of the shell and the other to embrace the belled-out end of a tubular shaft. The outer surface of this disc is flush with the outer surface of the shell.

The second row of blades is carried either (a) on a disc which abuts the upstream end of the shell, has an axial flange which extends into the end of the shell and is planed or rolled over behind an internal bead on the shell, and has integral with it a stub shaft to engage the front bearing of the rotor, or (b) by the shell itself which is made of bell-shaped form, the narrower end being in effect closed by an integral disc, the shell end being in this case formed with the stub shaft to engage the front bearing. In the latter case it is preferred to provide a separate ring on the narrower end of the shell to carry the blades.

The first stage blades are carried on a disc splined on and locked to the stub shaft on the upstream side of the bearing so that the bearing is located between the first and second stage rotor blades. The bearing may be carried from the casing of the associated stator by means of the ring of stator blades between these stages of rotor blades.

In a modification of the arrangement having the internal bead on the end of the shell, the bead is formed on a separate ring which is butt-welded to the end of the main shell portion which has a uniform thickness.

In another modification of the above arrangement, instead of the shell being of uniform thickness, local cylindrical lands are provided at the axial locations of the discs and narrow inwardly-directed beads formed

at the upstream ends of the lands. This enables the peripheries of the discs to be cylindrical and thus easier to fit, and enables the discs readily to be located.

The tubular shaft above referred to may be made in one piece to extend from the compressor rotor to the turbine or may be made in a number of parts butt-welded together. For instance, the belled-out part may be separate from the remainder which may be a cylindrical drawn tube.

During brazing of the parts together the discs may be located with respect to the shell by pegs passing through the shell into the disc rims.

The brazing may be carried out in a number of steps, say first brazing the shell to the discs at a comparatively high temperature and then the blades to the discs at a lower temperature.

The discs may have central holes to allow the passage of, say, oil pipes and these holes also allow "purging" of the rotor interior during brazing.

In yet another construction, the discs have a diameter substantially less than the internal diameter of the shell at their respective locations and the blades are elongated to be secured in the discs in a manner similar to that described above. The discs are located with respect to the shell each by means of a pair of sheet metal discs which are brazed to the faces of the blade-carrying discs and have flanges on their outer edges brazed to the shell.

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Fig.1A.

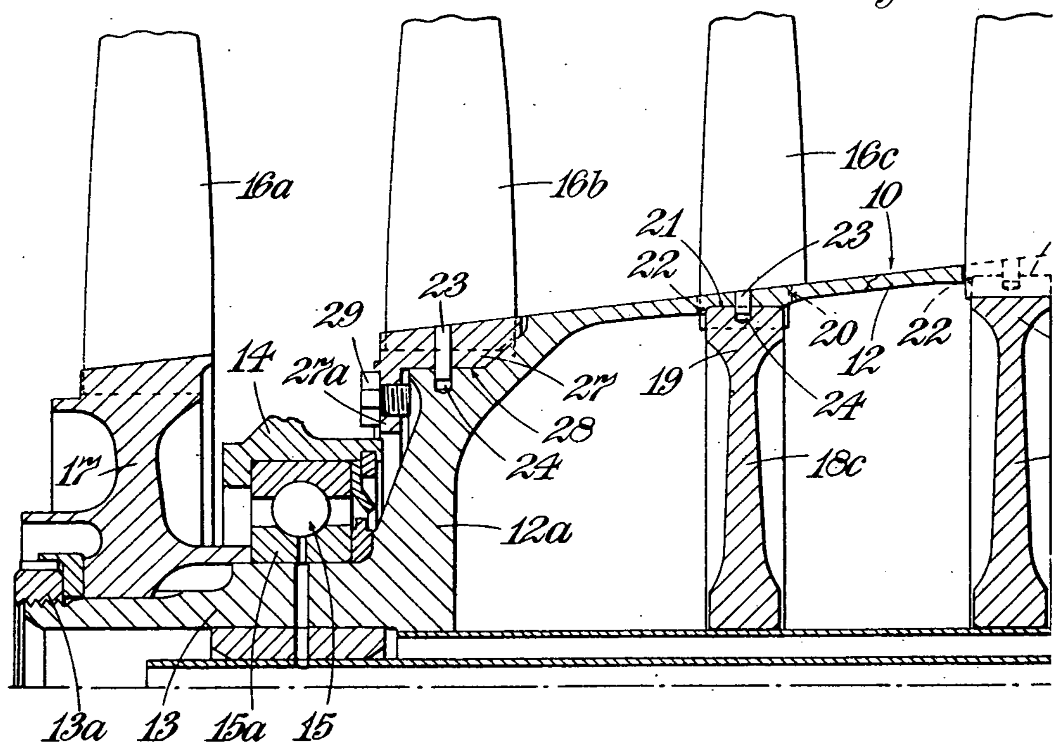
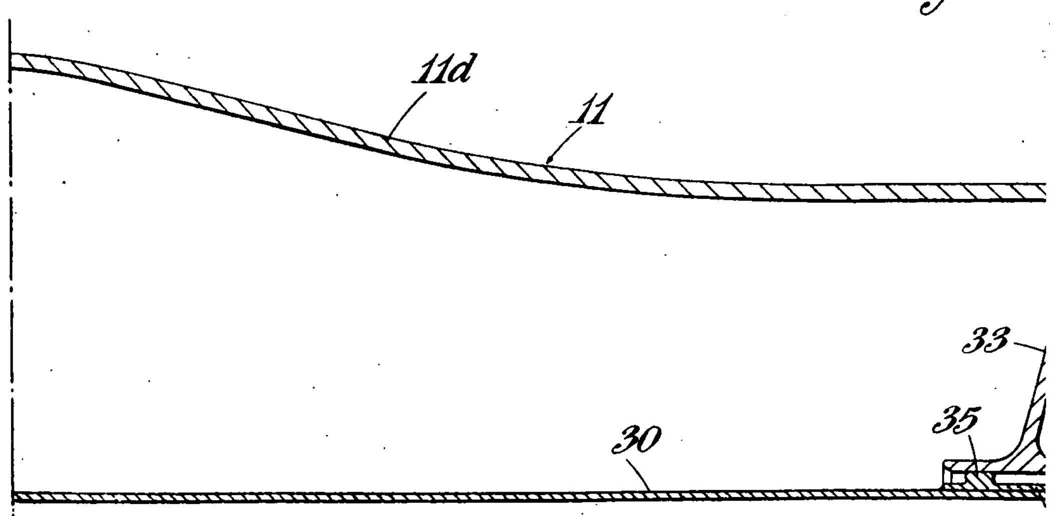


Fig.1B.



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SHEET 1

Fig.1A.

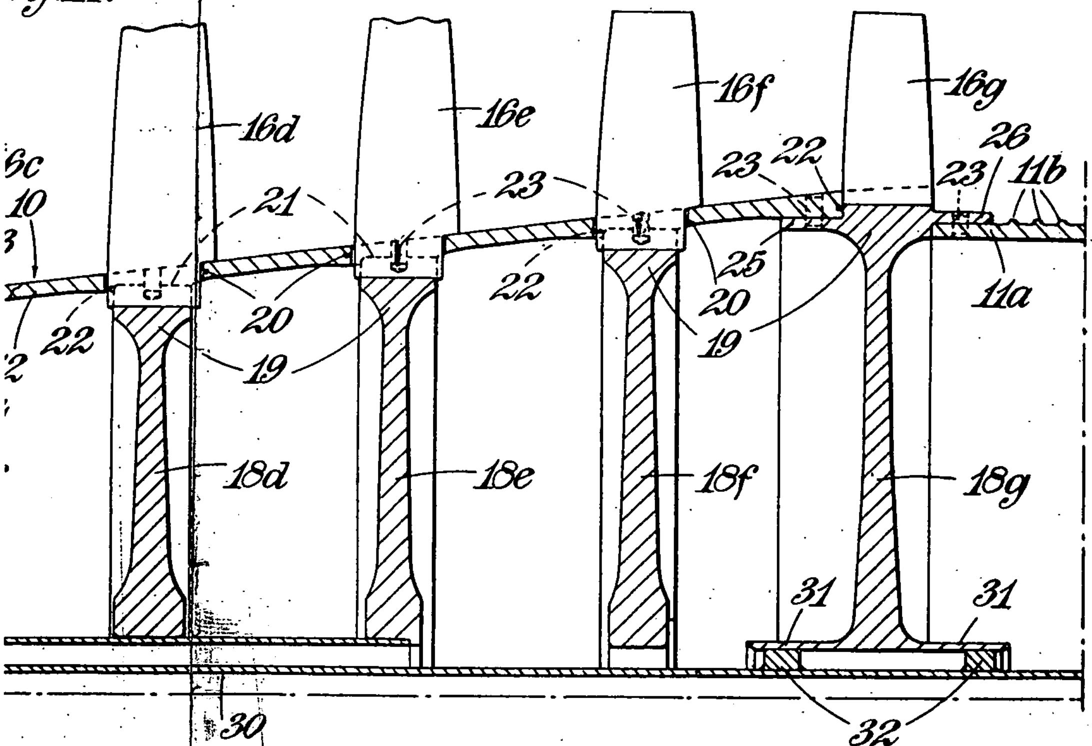


Fig.1B.

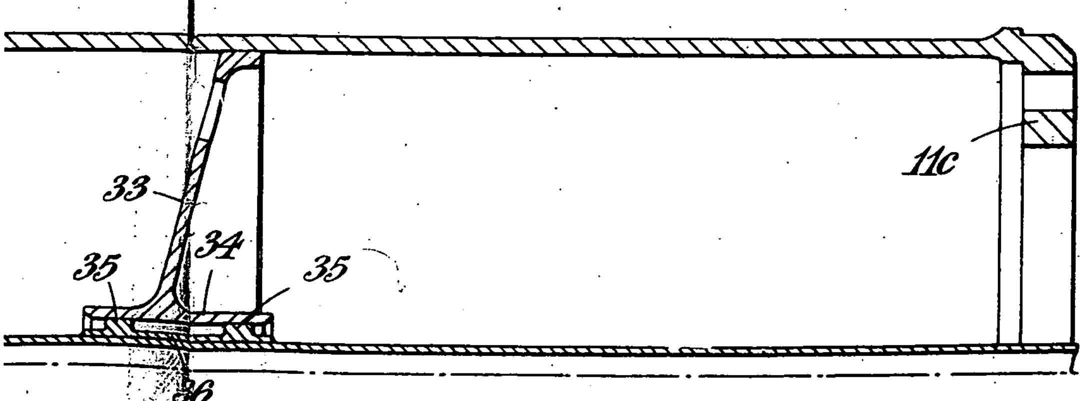


Fig.2.

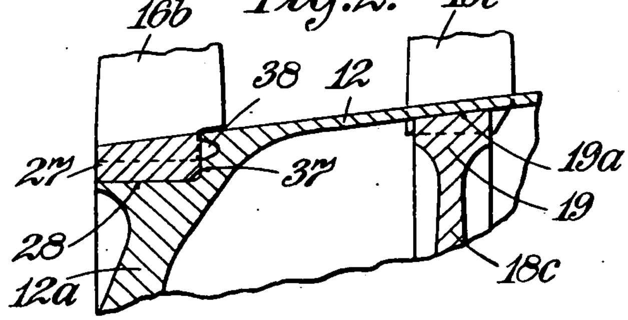
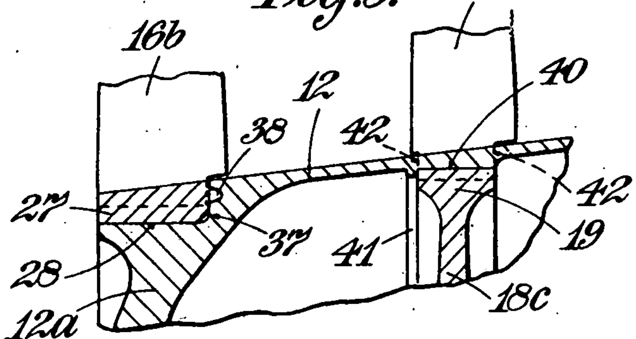


Fig.3.



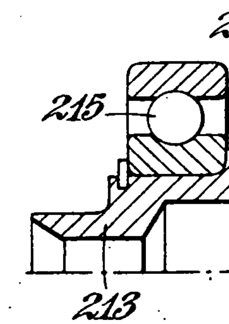
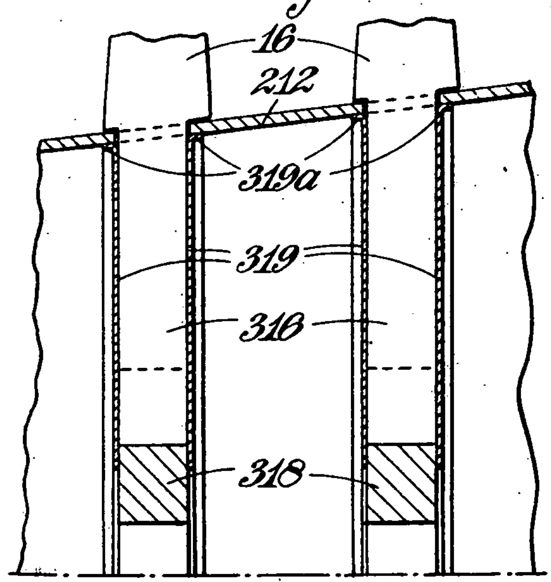
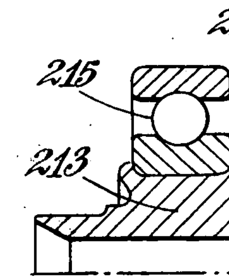


Fig.8.





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SHEET 2

Fig.6.

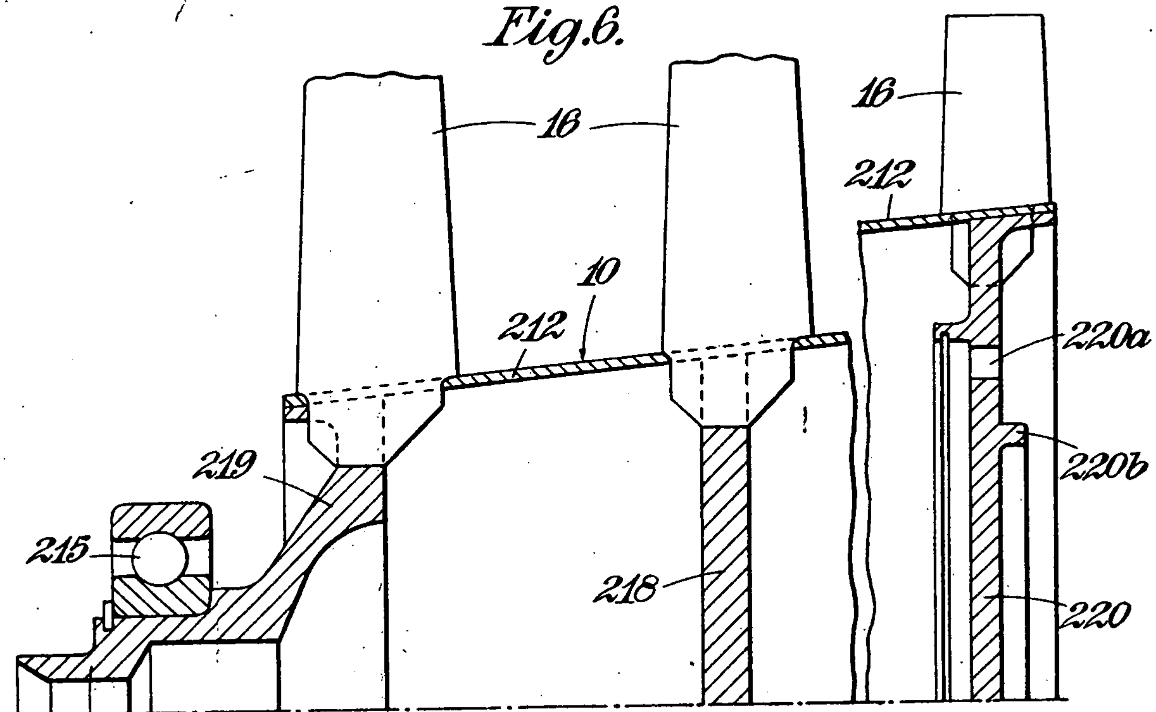
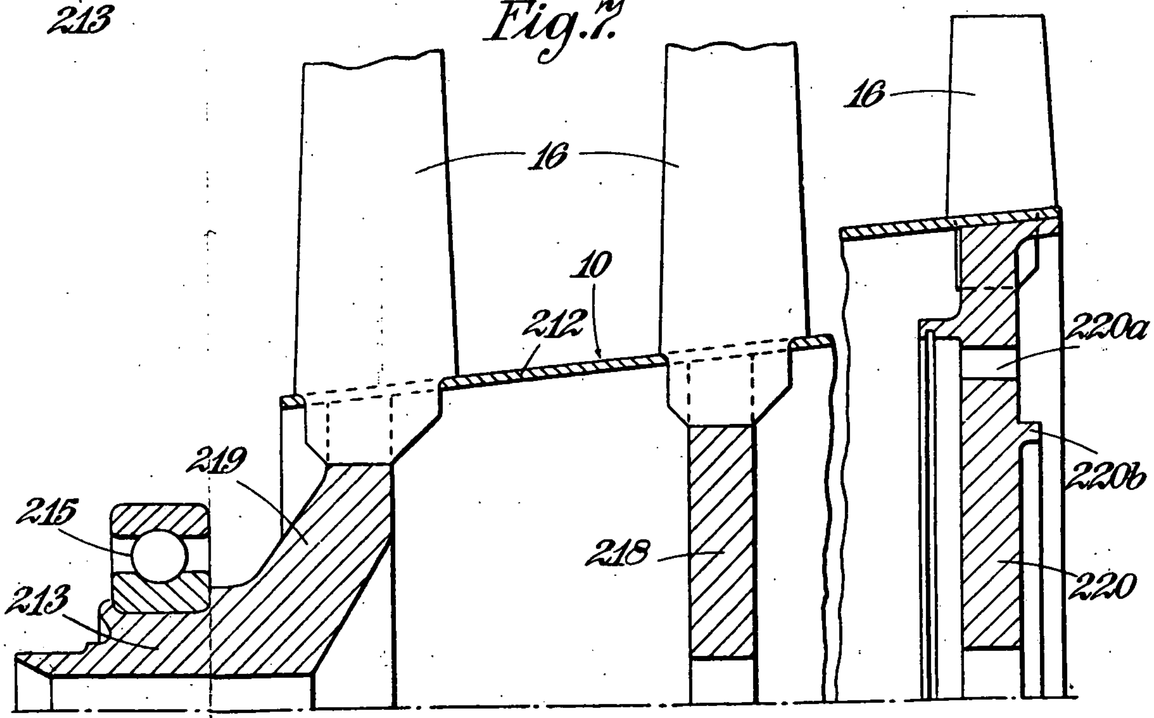


Fig.7.



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SHEET 3

Fig.4.

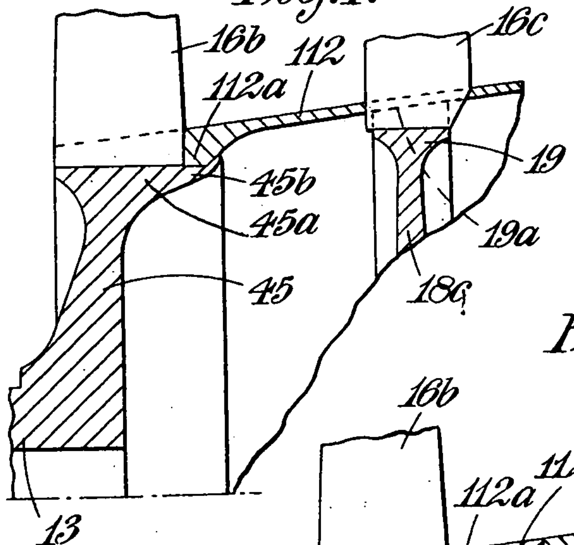

Fig.5.